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By George D. Wilson, Paul D. Brown, C. Edith Weir, Carol V. Pohl, W. R. Chesbro, and Betty Ginger

INTRODUCTION

The desire for adequate market supplies of tender, palatable beef is shared by the producer, processor, retailer, and consumer alike. Producers and processors have tried in a variety of ways to produce the kind of beef consumers want. Animal production research has indicated that considerable permanent improvement in the quality of cattle can be induced through selection (1)(3). This is a slow process, however, and several years will be required to bring about a noticeable change in the tenderness of beef displayed in the average supermarket meat counter.

A traditional method of tenderizing meat is to age or hang the carcasses for a period of two to four weeks at refrigerated temperatures. These aging procedures require a processor to carry a large inventory of beef and a proportionate investment in aging rooms and refrigeration equipment. Because these costs must be covered in the selling price of the aged meat, such procedures must be

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confined to a trade which will accept the additional cost. Further, the current aging methods are applied only to those carcasses with enough external finish to prevent the dehydration of the meat itself.

The purpose of the studies reported in this Bulletin was to investigate a method of accelerating the aging and tenderizing process sufficiently to make it practical for any beef carcass to be aged prior to shipment to the retail or wholesale trade. Interest was centered on the less highly finished grades of block beef because consumer surveys have shown a very definite preference for tender beef with a minimum of external fat. It was assumed that any treatment which was effective in tenderizing the lower grades of beef would also be effective on the higher quality beef now being aged.

The results of this study show quite conclusively that beef can be aged in 24 hours with the same degree of tenderization as is obtained in two weeks by conventional procedures. The temperature of aging (approximately 110°F.) is close to that of the hot carcass and the procedure thus eliminates the need for rapid chilling immediately after slaughter. While this temperature normally is conducive to bacterial growth, it has been shown that the pre-slaughter injection of a broad spectrum antibiotic, such as Terramycin, at a low tissue level is probably sufficient to control bacterial growth during the short aging period.

The limited scope of this project did not permit a full investigation of the commercial application of the rapid aging process but the results are sufficiently promising to warrant further consideration by the industry. With proper adaptation to commercial conditions, the high temperature aging process would reduce the time and cost of aging beef. It also would result in a major increase in

the amount of economical tender meat going into consumer markets.

General Considerations of Beef Tenderization

A number of different approaches have been used in the research directed toward improving the tenderness of beef. The results of some of the experimental procedures have been applied on a commercial scale while others still are under investigation. The improvement in tenderness through selection of breeding stock on the basis of tenderness, as well as other economically important characteristics, has been mentioned. A second approach to the improvement of tenderness is through the use of enzyme preparations which may be injected into the animal prior to slaughter (2) or applied to retail or portion-controlled cuts. Investigations of the latter type have been carried out at the American Meat Institute Foundation. These studies (14) have shown that enzymes from numerous plant sources may be used for this purpose and that some are quite selective with respect to action on muscle fibers or connective tissue.

Other investigators have found that meat can be tenderized by placing the frozen tissue in a high frequency field (9). This procedure has been confined to small samples of meat and the commercial possibilities have not been explored fully.

The basic changes which meat undergoes during aging at 35°F. are poorly understood but are thought to be due in part to the action of the proteolytic enzymes that are known to occur in muscle. A study of the enzymes which bring about this action is under way in our laboratories (13). That these natural meat enzymes play a significant role in tenderization during aging is indicated by the accelerated aging at temperatures in excess of 35°F.

McCarthy et al. (6) were the first to apply this principle in the commercial aging of meat. The "TENDERAY" process employed by the Kroger Company resulted from that company's investigations. More recently, other workers (10) (11) have aged beef for a relatively short time at 57° to 86°F. and obtained tenderization equivalent to that produced by aging for two weeks at 35°F.

Normally, enzyme activity increases with increasing temperatures up to the point where heat denaturation of the enzyme reduces its activity. If this is true for the natural enzymes involved in meat tenderization, one should expect optimum tenderization at a temperature somewhat higher than those employed in the experiments described above. The research project described below was designed to determine the optimum time and temperature for the rapid tenderizing of beef.

Aging Steaks at Elevated Temperatures

General Experimental Procedures. It was recognized in the planning of AMIF experiments that, during high temperature aging, the control of internal and external microbial growth would be a major consideration. New techniques developed in recent years for bacteriological control were, therefore, investigated. Because growth of many species of spoilage bacteria is inhibited at a pH of 5 or lower, the reduction of the pH of beef rounds by the arterial infusion of lactic acid was considered. The method was ineffective because the acid remained localized and discolored the meat. In these experiments, steaks were removed from the round as aging progressed and it was extremely difficult to reproduce specific muscle locations for the removal of samples from the control and aged rounds. In addition, the tenderness of the semimembranosus (top round) decreased as the sampling area was shifted from the anterior to the posterior area of the

muscle. For these reasons and because the internal temperature of intact rounds was not readily controlled, steaks were aged individually in much of the remainder of the study. Preliminary to further aging experiments, the tenderness pattern in the semimembranosus was established and taken into consideration in the experimental designs (5).

For the experiments, chilled top rounds from U.S. Good and Utility grade carcasses were purchased locally. In those experiments in which oxytetracycline (OTC) was used as a preservative during aging, the top round was stitch pumped to 106 per cent of its original weight with a solution containing sufficient antibiotic to provide the desired tissue level. It was recognized that this level is not commercially practical but it was used to insure the control of bacterial spoilage under the conditions of pumping and handling.

Following the antibiotic infusion, steaks, three fourths inches in thickness, were removed from the semimembranosus commencing at the separation between the wholesale round and rump. The steaks were rinsed with an antibiotic solution and then placed in Cry-O-Vac bags which were closed under vacuum.

The additional protection against spoilage required when aging at 90-100°F. was provided by irradiating packaged steaks in a gamma ray source at the Argonne National Laboratory, Lemont, Illinois. Preliminary studies showed that radiation at a level of 100,000 rad or more caused detectable flavor changes; therefore, all steaks were irradiated at approximately 45,500 rad.

Antibiotic injection and/or gamma radiation were used successfully to control microbial growth at aging temperatures up to 120°F. The growth of anaerobic

bacteria during aging was most difficult to control at 90° and 100°F. and, within this range, 20 to 50 p.p.m. of OTC (Terramycin) and 45,500 rads of gamma radiation were employed. At temperatures in excess of 100°F., antibiotic treatment alone was generally sufficient to control bacterial growth. It was recognized that this level of antibiotic may not be commercially practical but it was used to insure the control of bacterial spoilage under conditions of pumping and handling.

Evaluation of Tenderization During Aging. After aging, the steaks were broiled to an internal temperature of 150°F. (medium doneness). Complete details regarding the broiling procedure have been published by Weir et al. (15).

In this study, both the shear test and a taste panel were used to evaluate changes in tenderness due to aging. The available methods for the objective evaluation of tenderness have been reviewed by Schultz (8). The most widely used is the Warner-Bratzler Shear Method in which the force required to shear a small cylinder of meat is determined under controlled conditions. Generally, shear values correspond quite closely to taste panel scores when the cooked samples studied represent a wide range in tenderness. Using a modification of the procedure described by Cover (4), the taste panel scored the steaks for both initial tenderness and the amount of residual connective tissue remaining in the mouth after normal chewing. The latter tenderness factor is referred to as residue.

Results

Following the above procedures, steaks were aged at 60°F., 90°F., 100°F., 110°F., and 120°F. The growth of aerobic organisms during aging was effectively controlled by the antibiotic rinse and by vacuum packaging. Platings

of samples from aged steaks showed anaerobic counts from 10,000 to 250,000 organisms per gram depending on the aging temperature and the measures taken to control bacterial growth.

In the experiments conducted at 60°F., Utility grade rounds were infused with 20 p.p.m. of OTC and aged for 3 to 7 days. Adjacent steaks were held at 35°F. as controls. During this period of time there was an increase in the average tenderness score from 4.8 for the unaged steaks to 6.4 for the steaks held at 60°F. for 7 days (Table 1). It is not known whether further tenderization would have occurred if the aging period had been extended but extension of the holding time would not have been consistent with the objective of developing a rapid method of aging. Observations made by the taste panel members indicated that broiled samples from both the aged and unaged steaks contained large amounts of connective tissue and, in most of the subsequent experiments, rounds from U.S. Good grade carcasses were used.

In the second experiment, steaks were aged for 1, 2 or 3 days at 90°F. Preliminary work had shown that both antibiotic and gamma radiation treatment were required to control bacterial growth in packaged steaks held at 90°F. for three days. Eight pairs of inside rounds from U.S. Good grade carcasses were infused with 30-50 p.p.m. of OTC and irradiated prior to aging. Under these conditions of aging, the tenderness increased during the first and second day of aging but was slightly (but not significantly) lower following the third day (Table 1). These results indicated that significant tenderization could be obtained in two days at an aging temperature of 90°F. It is significant that the 90°F. aging temperature is near the optimum growth temperature for many spoilage organisms. The successful preservation of meat at this temperature for three days indicated that aging could be conducted

Table 1

Mean Tenderness Scores for Semimembranosus Steaks

Aged at 60 to 120°F.

Temp. °F.	Time	No. of Judgments	Panel[1] Score	Carcass Grade
60	0 days	54	4.8	Utility
	3 "	54	5.5	
	5 "	54	5.8	
	7 "	54	6.4	
90	0 days	96	5.4	Good
	1 day	96	6.0	
	2 days	96	6.5	
	3 "	96	6.2	
100	0 hrs.	114	5.3	Good
	48 "	114	6.0	
110	0 hrs.	42	5.7	Utility
	16 "	42	6.2	
	24 "	46	7.4	
	40 "	22	5.7	
110	0 hrs.	40	6.0	Good
	16 "	44	6.9	
	24 "	41	7.6	
	40 "	14	6.9	
120	0 hrs.	106	5.2	Good
	24 "	106	7.4	

[1]Score Range: 1-10 with increasing tenderness.

experimentally at any temperature at which the native enzymes would be active.

Because less involved procedures could be employed if the temperature was raised, a third experiment was designed in which steaks were aged for 16, 24, and 40 hours at 110°F. Eight U.S. Good rounds and eight U.S. Utility rounds were infused with 50 p.p.m. of OTC. This treatment alone was sufficient to control bacterial growth for the maximum aging time. A similar response to high temperature aging was obtained in the two grades (Table 1). Control steaks held at 35°F. for similar periods of time changed relatively little in tenderness while a significant improvement was noted in adjacent steaks aged at 110°F. The maximum tenderness occurred after 24 hours of aging. Steaks from both grades held for this period at 110°F. had an average panel score of 7.5 compared to the unaged steaks which had an average score of 5.8. The score of 7.5 exceeded any previous scores for aged steaks and it was assumed that this time-temperature treatment approximated the optimum aging conditions. To verify this assumption, a further experiment was conducted in which temperatures ten degrees above and below 110°F. were studied.

Semimembranosus steaks were aged at 120°F. for 24 hours and at 100°F. for 48 hours and were compared with similar steaks aged at 110°F. for 24 hours. The steaks aged at 100°F. received 45,500 rads of gamma radiation after packaging and prior to aging. The results showed an increase in tenderness at 120°F. which was greater than at either 100°F. or 110°F. However, it was noted that following aging at 120°F. the pigments of the steaks were generally oxidized and the panel members objected to the dryness and "warmed-over" flavor of the broiled steaks. This information suggested that the increased tenderness at 120°F. was due partially to a

cooking effect under the moist heat conditions present at the time of aging and was not solely a result of enzymatic activity. The tenderness of the steaks aged at 100°F. was significantly improved over the unaged controls but the improvement was less marked than in those aged at the two higher temperatures. The greater ease with which microbial growth was controlled at 110°F. and the undesirable changes associated with aging at 120°F. gave further indication that 110°F. was near optimal for the rapid tenderizing of beef steaks.

In the experiments described above the effectiveness of an aging treatment was determined by comparison with steaks held at 35°F. for the same time period. While the results at higher aging temperatures showed a definite improvement in tenderness, a comparison was needed between the most acceptable accelerated aging procedures and a more conventional procedure. Using procedures similar to those of previous experiments, it was found that the steaks aged at 35°F. for two weeks increased in average tenderness score from 5.2 to 5.9, while those aged at 110°F. for 24 hours increased from an average of 5.3 to 6.3. The difference between treatments was not statistically significant, indicating that the two methods of aging were comparable.

These results were indicative that the aging at 110°F. could be carried out in carcasses and, in the remainder of the study, the laboratory results were applied to the aging of beef carcasses immediately following slaughter.

Aging of Beef Carcasses at 110°F.

Experimental Procedures. The application of the results obtained in the laboratory experiments was limited to the aging of five beef carcasses. Much more extensive

trials under commercial conditions will be required to fully evaluate the accelerated aging procedure but the work reported here outlines general procedures that might be used and indicates the commercial potentiality of the process.

For the carcass studies, steers which would yield a 500 to 600 pound carcass in the U.S. Good grade were selected. The first animal received 10 gms. of oxytetracycline (Biostat)[1] in 100 ml. of solution intraperitoneally immediately posterior to the thirteenth rib (near the middle of the paralumbar fossa on the right side). This was administered while the animal was in a holding chute in a crouched position and it was found after slaughter that much of the solution had lodged in the muscle tissue of the body wall. This limited severely the availability of the antibiotic for distribution throughout the body. Because of the difficulty associated with this injection procedure, the remaining four animals received 5-8 gms. of the antibiotic in 40-50 ml. of solution in the distal portion of the tail. This procedure, which had been described by other workers (7) (12), had the advantage of relative ease of administration and the localized inflammation resulting from the injection was confined to a portion of the carcass having limited value.

Immediately following dressing, the carcasses were transported to the American Meat Institute Foundation laboratories to undergo aging. Two to three hours elapsed between slaughter and placing the carcasses under the desired aging conditions. To compensate for the reduction in carcass temperature during transport, the side aged at the high temperature was maintained at 120°F. until the ribeye temperature approached 110°F. Under plant conditions, this reduction in temperature could be

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[1]Supplied by Chas. Pfizer & Co., Inc.

readily avoided by placing the carcass into a room maintained at 110°F. immediately following dressing. The internal temperature of the rounds was 103° to 106°F. three hours after slaughter and rose to a maximum of 108°F. during high temperature processing. After 24 hours of aging at 110°F., the sides were chilled at 20°F. for 15 hours and then held at 35°F. Control sides underwent a similar chilling immediately following slaughter and were then aged for 14 days at 35°F.

The wholesale rib and hind quarter from one side of each carcass was aged at 110°F. To determine the extent of tenderization occurring under these conditions, steaks were removed from the short loin (longissimus dorsi) posterior to the thirteenth rib and compared with similarly located steaks from the opposite unaged short loin. Steaks from the semimembranosus (top round), semitendinosus (bottom round) and biceps femoris (bottom round), and the longissimus dorsi (rib) of the side aged at 110°F. were compared with similarly located steaks from the opposite side which had undergone two weeks of aging at 35°F.

The preservative effect of the antibiotic treatment was determined by bacteriological examination of samples removed from representative steaks prior to the taste panel evaluation. In addition, one ml. of supernatant from a meat homogenate was administered to mice intraperitoneally to determine safety.

Results

Procedures employed for distribution of the antibiotic in the muscle prior to slaughter resulted in levels of 0.3 to 1.6 p.p.m. OTC[2] in the ribeye after aging for

[2]Assays performed by Chas. Pfizer & Co., Inc.

one day at 110°F. or 14 days at 35°F. The lowest tissue level of antibiotic occurred in the fourth animal, which received five grams of OTC in the tail and was slaughtered two hours after receiving the antibiotic. The highest tissue level of antibiotic was found in the animal which received 8 grams of OTC by tail injection and was slaughtered three hours after injection. The first carcass, which received only part of the intended intraperitoneal injection, had a tissue level of 0.4 p.p.m. The antibiotic level in the livers at time of slaughter was 7 to 9 times that found in the muscle tissue.

During aging at 110°F., the relative humidity in the chamber was maintained at 80 to 90 per cent. A relative humidity of 85 to 90 per cent was found to be most desirable. Surface microbial growth was controlled at this humidity without the addition of an externally applied bacteriostatic agent and shrinkage was minimized.

Because of sampling for pH determinations and taste panels during aging, it was difficult to obtain an accurate comparison of shrinkage by the two aging procedures. The limited data which were obtained indicated that shrinkage occurred to about the same degree in aging at 110°F. for 24 hours and at 35°F. for 14 days.

During processing, a more rapid drop in pH (more rapid acid production) occurred at 110°F. than at 35°F., although after 26-28 hours the pH of both sides had reached values within the normal range of chilled beef.

With the exception of the second carcass processed, populations of anaerobic bacteria did not exceed 10,000 per gram in the rib or 80,000 per gram in the round. Extensive anaerobic growth did occur in the samples removed from carcass No. 2 and these samples also had a low staphylococcus count. The injection of mice with water

Table 2

Mean Tenderness Scores and Shear Values of Steaks from Carcasses Aged at 35 and 110°F.

Muscle	Tenderness Scores 35°F. 2 wks.	Tenderness Scores 110°F. 24 hrs.	No. of Judgments	Shear Values 35°F. 2 wks.	Shear Values 110°F. 24 hrs.
Long. dorsi (loin eye)	7.8	7.8	118	7.9 (77)[1]	8.5 (72) 9.7 (81)
Semitendinosus (bottom round)	7.4	6.9	122	9.0 (97)	
Semimembranosus (top round)	6.2	6.5	126	13.0(109)	10.8(104)
Biceps femoris (bottom round)	6.9	6.5	112	11.1(118)	10.8(102)
All Muscles	7.1	6.8	478	10.5(401)	10.1(359)

[1] Number of shear values.

extracts of the same aged muscles had no adverse effect. The antibiotic tissue level in this particular carcass was comparable to that found in other carcasses.

Considering the data which are available regarding the bacteriological control during aging, we are of the opinion that the extensive anaerobic growth in the cultures of the second carcass was initiated by contaminants introduced at the time of sampling and was not an indication of bacterial growth during aging. Evidence for this assumption was not sufficient, however, to permit taste panel evaluation of this carcass and only shear values were obtained.

Samples taken from the ribeye of the short loin after 24 hours of aging at 110°F. showed a marked increase in tenderness when compared with unaged controls. The average taste panel score for the aged and unaged steaks was 7.4 and 4.7, respectively. A more detailed comparison between aging at 110°F. for 24 hours and aging at 35°F. for two weeks was made possible by using four muscles from each carcass. The data show that slightly more tenderization occurred in the longissimus dorsi, semitendinosus, and biceps femoris when conventional aging procedures were employed (Table 2). The tenderness scores for the semimembranosus muscles were highest when aging was conducted at 110°F. Considering only the latter muscle, which was the one used when individual steaks were aged, there was good agreement between the two aging methods. It is significant that the semimembranosus is the least tender of the muscles tested as this would indicate that the high temperature aging procedure is more effective for the less tender muscles of the carcass.

The combined scores for all muscles show a slight but significantly greater tenderization for aging at 35°F.

For carcasses, as well as individually aged steaks, the taste panel scores for residue were related closely to tenderness scores and did not provide a more critical analysis of tenderization during aging.

An inspection of the values in Table 2 for individual muscles shows a rather good agreement between panel scores and shear values. Differences in over-all response (mean scores) to the two methods of measuring tenderness may be due to an inproportionate number of values for the four muscles.

The taste panel was asked to score the steak samples for flavor and aroma in addition to tenderness. A tabulation of these scores indicated some preference for those steaks from sides or ribs aged at 35°F. Scores for flavor and comments regarding the nature of flavors of the aged carcasses showed that the changes were much less pronounced than when individual steaks were aged.

DISCUSSION

These experiments show that the aging of beef can be accelerated greatly at elevated temperatures. In aging carcasses at 110°F., the ante-mortem injection of a broad spectrum antibiotic appears to provide adequate bacteriological control. The great difference in the effective concentration of antibiotic, which was used in stitch pumped cuts and the intact carcass cuts, can be attributed to contamination during stitch pumping and handling and the more uniform distribution of the antibiotic when it is administered to the live animal. After injection into the animal, the antibiotic is carried by the blood and lymphatic system and therefore attains a significant concentration in the lymph nodes. Weiser et al. (16) have shown that the lymph nodes in the deep tissues of the round and other cuts are frequently the source of internal spoilage

organisms.

The results obtained on five carcasses are sufficiently promising to warrant further investigation of the commercial potentialities of the high temperature aging procedure. It is recognized that a trained taste panel is frequently more critical of flavor changes than the average consumer but it is thought that the change in flavor was sufficiently evident to make this a consideration in an extension of these studies. In many respects, the flavor of beef aged at 110°F. resembled that of meat which has been aged for an extended time at 35°F. Because of the simplicity which antibiotic preservation offers, it would be advantageous to stay within a temperature range where only an antibiotic is required to control spoilage. Time periods of less than 24 hours were not included in the carcass study. It seems quite possible that both a lower temperature and a shorter time could provide a tenderizing effect equal to those noted in the present study without affecting the flavor to a significant degree.

Rather wide differences in tenderness exist between beef from the various grades and some consideration should be given to the effect that such variations may have upon the time and temperature of aging.

In considering an expansion of the present study, very careful attention must be given to the adequacy of the preservative treatment which is employed. Such studies should be undertaken only with the guidance and assistance of qualified personnel and with the knowledge that antibiotics and high energy radiations are not presently approved by regulatory agencies for use in the preservation of red meat.

SUMMARY

Beef increases significantly in tenderness when it is

aged for 24 hours at 110°F. immediately post-slaughter. Results obtained with beef aged as individual steaks and as carcasses indicate that the tenderization which occurs is generally comparable to that obtained when beef is aged for two weeks at 35°F. The data indicate that bacterial growth during aging can be satisfactorily controlled by pre-slaughter administration of a broad spectrum antibiotic. It would appear that this procedure offers promise as one of the important approaches available to the meat industry to achieve increased tenderness of beef cuts. With the information obtained in this study, an extension of the experiments to plant conditions should be the next step in evaluating the ultimate commercial potentialities.

PUBLICATIONS

More detailed and technical reports of these investigations have been prepared and submitted to Food Technology for publication. The first paper (17) describes the experiments using steaks and the second (18) gives a more detailed description of the carcass studies. These will be available for distribution at a later date.

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LITERATURE CITED

1. Alsmeyer, R. H., A. Z. Palmer, M. Koger and W. G. Kirk. The relative significance of factors influencing and/or associated with beef tenderness. Proceedings of the Eleventh Research Conference, p. 85. American Meat Institute Foundation, 1959.

2. Beuk, Jack F., Alfred L. Savich, Paul A. Goeser and John M. Hogan. Method of tendering meat. U. S. Patent 2,903,362 (Sept. 8, 1959).

3. Cartwright, T. C., O. D. Butler and Sylvia Cover. Influence of sires on tenderness of beef. Proceedings of the Tenth Research Conference, p. 75. American Meat Institute Foundation, 1958.

4. Cover, S. Scoring for three components of tenderness to characterize differences among beef steaks. Food Research 24, 564 (1959).

5. Ginger, Betty and C. Edith Weir. Variations in tenderness within three muscles from beef round. Food Research 23, 662 (1958).

6. McCarthy, J. F. and C. G. King. Some chemical changes accompanying tenderization of beef. Food Research 7, 295 (1942).

7. Sacchi, E. M., J. R. McMahan, R. C. Ottke and C. L. Wrenshall. New methods of preslaughter administration of antibiotics. Presented at the Seventeenth Annual Meeting of the Institute of Food Technologists, May 12-16, 1957.

8. Schultz, H. W. Mechanical methods for measuring tenderness of meat. Proceedings of the Tenth Annual Reciprocal Meat Conference, p. 17. National Live Stock and Meat Board, 1957.

9. Simjian, L. G. Method of tenderizing foods. U. S. Patent 2,830,912 (April 15, 1958).

10. Sleeth, R. B., R. L. Hendrickson and D. E. Brady. Effects of controlling environmental conditions during aging on the quality of beef. Food Technol. 11, 205 (1957).

11. Sleeth, R. B., G. G. Kelley and D. E. Brady. Shrinkage and organoleptic characteristics of beef aged in controlled environments. Food Technol. 12, 86 (1958).

12. Sleeth, R. B. and H. D. Naumann. Efficacy of oxytetracycline for aging beef. Food Technol. 14, 98 (1960).

13. Sliwinski, R. A., D. M. Doty and W. A. Landmann. Overall assay and partial purification procedures for proteolytic enzymes in beef muscle. J. Agr. Food Chem. 7, 788 (1959).

14. Wang, H., C. Edith Weir, Marion L. Birkner and Betty Ginger. The influence of enzymatic tenderizers on the structure and tenderness of beef. Proceedings of the Ninth Research Conference, p. 69. American Meat Institute, 1957.

15. Weir, C. Edith, H. Wang, Marion L. Birkner, J. Parsons and Betty Ginger. Studies on enzymatic tenderization of meat. II. Panel and histological analyses of meat treated with liquid tenderizers containing papain. Food Research 23, 411 (1958).

16. Weiser, H. H., H. S. Goldberg, V. R. Cahill, L. E. Kunkle and F. E. Deatherage. Observations on fresh meat processed by the infusion of antibiotics. Food Technol. 7, 495 (1953).

17. Wilson, G. D., P. D. Brown, W. R. Chesbro, Betty Ginger and C. Edith Weir. The use of antibiotics and gamma irradiation in the aging of steaks at high temperatures. Food Technol. 14, 143 (1960).

18. Wilson, G. D., P. D. Brown, Carol Pohl, C. Edith Weir and W. R. Chesbro. A method for the rapid tenderization of beef carcasses. Food Technol. Accepted for publication (April, 1960).